

# Assessing the Direct Costs of Treating Nonvalvular Atrial Fibrillation in the United States

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## ABSTRACT

**Objective:** To determine the health-care resource use and costs attributable to treating atrial fibrillation (AF) in the United States.

**Methods:** Retrospective analyses of three federally funded US databases (2001 data): 1) hospital inpatient stays (the Healthcare Cost and Utilization Project [HCUP]); 2) physician office visits (the National Ambulatory Medical Care Survey [NAMCS]); and 3) emergency department (ED) and hospital outpatient department visits (OPD) (the National Hospital Ambulatory Medical Care Survey [NHAMCS]). Identification of AF medical encounters was based on occurrence of AF-specific International Classification of Diseases (9th Edition)—Clinical Modification (ICD-9-CM) diagnosis code 427.31 (principal discharge diagnosis for inpatient setting; any diagnosis field for other settings). For the 10 most common principal discharge diagnoses in the inpatient setting, case-control comparison analyses were performed to estimate annual incremental costs of AF as a comorbid discharge diagnosis for hospital stays. Regression models were

used to assess the impact of AF on hospitalization costs. Costs were estimated in year 2005 US dollars.

**Results:** Approximately 350,000 hospitalizations, 5.0 million office visits, 276,000 ED visits, and 234,000 OPD were attributable to AF annually within the United States. Total annual costs for treatment of AF were estimated at \$6.65 billion, including \$2.93 billion (44%) for hospitalizations with a principal discharge diagnosis of AF, \$1.95 billion (29%) for the incremental inpatient cost of AF as a comorbid diagnosis, \$1.53 billion (23%) for outpatient treatment of AF, and \$235 million (4%) for prescription drugs. In all regressions, AF was a significant contributor to hospital cost.

**Conclusions:** Treatment of AF represents a significant health-care burden with the costs of treating AF in the inpatient setting outweighing the costs of treating AF in the office, emergency room or hospital outpatient settings. Further research is needed to fully capture the costs of treating AF.

**Keywords:** atrial fibrillation, cost, resource use, retrospective study.

## Introduction

Atrial fibrillation (AF), the most common sustained cardiac arrhythmia encountered, currently affects approximately 2.2 million people in the United States [1] and increases in prevalence with age. Given the impending increase in the elderly population, AF is anticipated to become an increasing burden on the health-care system with Go et al. [2] estimating a 2.5-fold increase in number of patients with AF over the next 50 years. Nevertheless, despite the high prevalence of AF, little has been done to evaluate the overall economic burden of this disease. The majority of the economic studies on AF have been conducted in the United States with a hospital or third-party payer perspective using decision modeling to estimate the costs

of specific treatments. These studies focused specifically on costs associated with either interventional procedures [3–6], anticoagulation and stroke prevention [7–13], or pharmacological treatments [3,7–10,12,14–17]. Studies examining the “national” cost of AF have been conducted in the UK [18] and France [12], however, the overall cost of treating AF in various health-care settings has not been examined in the United States. As such, the objective of this study was to determine the impact of AF on health-care resource use and costs in the hospital inpatient, outpatient, and office visit settings in the United States.

## Methods

### Data Sources

Three separate, cross-sectional, federally funded, and nationally representative medical encounter databases were analyzed, including: 1) The Healthcare Cost and Utilization Project's (HCUP) Nationwide Inpatient Sample database (2001); 2) The National Ambulatory

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Medical Care Survey (NAMCS) database (2001); and 3) The National Hospital Ambulatory Medical Care Survey (NHAMCS) database (2001). HCUP contains hospital discharge data from a 20% sample of US hospitals. The hospital sampling frame is defined as community hospitals (including public hospitals, academic medical centers and specialty hospitals) that were open during any part of 2001. Each hospital stay record contains: patient age, sex, principal and comorbid discharge diagnoses, medical or surgical procedures/tests, length of stay, and total billed charges. Fees for physician services are not included in HCUP.

NAMCS contains annual physician office visit data from an approximate 0.3% sample of US physician offices. Each visit record includes: age, sex, up to three listed diagnoses, drugs prescribed, and diagnostic and medical or surgical procedures/tests performed during the visit. NHAMCS contains annual emergency room (ER) and hospital outpatient department (OPD) visit data from an approximate 10% sample of US short-stay (average length of stay [LOS] < 30 days) hospitals. NHAMCS variables are similar to those included in NAMCS.

For each database, each of the discharge or visit records in the databases contains a weighting variable that was utilized in analyses to provide nationally representative estimates.

#### Identification of AF-Related Medical Encounters

Identification of AF-related encounters in the inpatient setting was based on the designation of the International Classification of Diseases (9th Edition)—Clinical Modification (ICD-9-CM) diagnosis code 427.31 (atrial fibrillation) as either the principal or comorbid discharge diagnosis. Hospitalizations with a valvular-related diagnosis (ICD-9-CM 093.20, 394.0, 424.0, 746.3) were excluded from this analysis.

For the NAMCS/NHAMCS analyses, a visit record qualified as AF-related by one of four ways: 1) the AF diagnosis code was the only listed code on the record;

2) the AF diagnosis code was listed among other codes, but one of the “reason for visit” codes included cardiovascular disease; 3) a drug used to treat AF was prescribed; or 4) a procedure related to AF was performed.

#### Inpatient Costs of AF

The economic perspective was that of a third-party payer. HCUP provides information on total billed charges, excluding physician fees, for a given discharge but not the actual costs of providing services, which more closely relates to the amount reimbursed by payers. Hospital-specific cost-to-charge ratios are not provided therefore an average cost-to-charge ratio of 0.53, estimated from publicly available Medicare Cost Report Data for 2001 [19], was applied to the total billed charges. The cost estimates based on 2001 data were updated to year 2005 US dollars based on the Consumer Price Index for hospital inpatient services (conversion factor of 1.275 to adjust 2001 to 2005 dollars) [20].

The cost estimate for AF in the inpatient setting includes two principal components: 1) costs due to AF as a principal discharge diagnosis; and 2) costs attributable to AF as a secondary (comorbid) discharge diagnosis. For the first component, the full costs of hospitalizations with a principal discharge diagnosis of AF were attributed to AF. Costs for inpatient physician services were estimated based on Medicare’s National Average Allowance for specific evaluation and management service codes for 2005 [21]. Code 99211 was applied to the initial day of hospitalization, code 99238 to the day of discharge, and code 99231 for all days in between.

For the second component, a case-control comparison was utilized to estimate the “incremental” economic impact of AF. This analysis focused on the 10 most common principal discharge diagnoses in HCUP with AF as a comorbid diagnosis (Table 1). Hospitalizations with one of the 10 principal discharge

**Table 1** Top 10 HCUP diagnoses with atrial fibrillation as a comorbid diagnosis (2001)

Primary diagnosis	Total count*	Count with AF	Percent	No. per group	Mean age (SD)	Proportion female (%)	Proportion white (%)
428.0—CONGESTIVE HEART FAILURE	803,606	221,201	31.5	33,289	77.3 (10.7)	51.7	85.0
486—PNEUMONIA, ORGANISM NOS	773,994	114,200	15.8	16,707	79.9 (9.8)	50.9	90.1
414.01—CRNRY ATHRSCL NATVE VSSL	1,008,625	105,980	15.1	16,295	71.7 (9.5)	34.5	88.6
410.71—SUBENDO INFARCT, INITIAL	334,746	55,160	7.8	8,364	76.3 (10.3)	44.5	88.8
491.21—OBS CHR BRNC W ACT EXA	484,393	50,064	7.1	7,633	75.8 (9.1)	48.9	90.8
434.91—CRBL ART OCL NOS W INFR	226,596	34,576	4.9	5,176	79.7 (9.0)	61.2	86.4
276.5—HYPOVOLEMIA	384,545	33,403	4.8	4,919	81.1 (9.3)	61.5	88.3
507.0—FOOD/VOMIT PNEUMONITIS	173,539	30,597	4.4	4,594	82.8 (8.5)	43.5	89.2
427.81—SINOATRIAL NODE DYSFUNCT	74,166	30,318	4.3	4,525	77.9 (8.6)	52.3	92.5
599.0—URIN TRACT INFECTION NOS†	273,783	29,078	4.1	4,359	82.3 (8.4)	66.3	87.2

\*The sample discharges for each diagnosis were weighted to be nationally representative based on the discharge-level weights provided in the Healthcare Cost and Utilization Project (HCUP).

†The primary diagnosis “V578.9—Rehabilitation procedures” (number 6 in frequency) was not included in this analysis because of the heterogeneity of this diagnosis. To compensate, diagnosis “599.0—Urinary tract infection” (number 11 in frequency) was included in the analysis.

Source. 2001 HCUP.

diagnoses and a comorbid diagnosis of AF, were separated into 10 distinct “case” groups based on the principal discharge diagnosis. Controls for each specific principal discharge diagnosis were selected from the pool of hospitalizations that did not include a comorbid diagnosis of AF. Each case was matched to a control on the following variables: age, sex, race, principal discharge diagnosis, and bed size category of hospital (i.e., large, medium, small).

### *Outpatient Costs of AF*

Neither costs nor charges are reported in NAMCS/NHAMCS; thus, to estimate the costs associated with AF-related visits, the resource use items (i.e., drugs, procedures) recorded were assigned unit costs and then summary costs calculated.

The NAMCS office visit records include the amount of time the patient spends with the doctor. This time was averaged for all AF visits, and the appropriate evaluation and management Current Procedural Terminology (CPT) code was assigned. For physician fees for the emergency department (ED) and OPD settings, the lowest level of visit complexity was assumed in each setting to provide the most conservative cost estimate. The unit costs for the chosen CPT codes were based on national prevailing fees for 2004 [21], updated to year 2005 US dollars based on the Consumer Price Index for hospital outpatient services (conversion factor of 1.05 for the period between 2004 and 2005) [22].

Each visit record includes up to a maximum of six medications that were prescribed during the visit. The medication name is reported, but not the days supplied or daily dose. Therefore, each drug was assigned an estimated “days supplied” and “daily dose” amount based on drug-specific recommendations in the Physician’s Desk Reference (PDR). The default value for days supplied was “30” for the office or OPD setting and “1” for the ER setting if the PDR did not specify a length of therapy. Drug costs were estimated based on the average wholesale price reported in the 2004 Drug Topics RED BOOK, updated to year 2005 US dollars based on the Consumer Price Index for prescription drugs (conversion factor of 1.05 for the period between 2004 and 2005) [23]. Oral intake was assumed for all estimated drug costs. The cost analysis included only drugs used to treat AF, as determined by a review of all recorded medications by two expert clinicians.

Facility costs (for ED and OPD settings) were estimated based on publicly available claims data utilized by the CMS to develop the Outpatient Prospective Payment [24]. Facility costs were updated to 2005 using the Consumer Price Index for hospital outpatient services [22].

### *Statistical Analyses*

All statistical analyses were conducted using SAS (Release 8.02; SAS Institute Inc., Cary, NC, USA).

Where appropriate for counts, frequency distributions or means, the weight variables in the databases were utilized to provide accurate national estimates. Because of the large sample sizes, statistical tests were considered significant at  $P < 0.001$ . Nonparametric Wilcoxon rank sum tests were used to test for statistical significance due to non-normal data distributions [25].

An ordinary least squares (OLS) regression model was used to assess the contribution of certain factors in predicting total charges for AF hospitalizations. Charges were transformed into logarithms due to skewed distributions (i.e., long tails of expensive hospitalizations). The regression model included: age, sex, race, expected primary payer, bed size of hospital, emergency admission, surgery performed not related to principal discharge diagnosis (based on record of any surgical diagnosis-related groups), and comorbidities (yes/no for each of 30 comorbidity variables developed and validated by Elixhauser et al. [26] for use in predicting costs with administrative data; for all models, the comorbidity of cardiac arrhythmias was excluded).

OLS regression models were also used in the case-control comparison to assess the incremental cost of AF on total charges for each of the 10 case-control matches. The model structure was the same as described in the above paragraph except for the addition of the case-control status variable. To allow for a direct interpretation (i.e., in dollar terms) of the parameter estimates from the log-transformed models, a “smearing” or retransformation factor was applied to each regression model [27]. Once the incremental charges per hospitalization due to AF were estimated for each of the 10 principal discharge diagnoses, the charges were converted to costs and then multiplied against the annual number of hospitalizations in the United States that included the respective principal diagnoses and a comorbid diagnosis of AF.

## **Results**

### *Inpatient Analyses*

There were an estimated 348,131 hospitalizations in the United States in the year 2001 with AF listed as the principal discharge diagnosis. Consistent with the epidemiology of AF, the majority of hospitalizations involved patients ages 65 years and older (72%), with 13% ages 85 and older. Approximately 54% of the AF hospitalizations involved female patients and a large majority (88%) involved white patients. The most frequent comorbid conditions for patients hospitalized with a primary diagnosis of AF were hypertension (36%), congestive heart failure (CHF) (19%), coronary atherosclerosis (18%), and chronic obstructive pulmonary disease (COPD) (10%). Echocardiography was the most commonly performed procedure during

**Table 2** Number of atrial fibrillation (AF) hospitalizations, average length of stay, average costs per stay, and total costs, 2001

Description	Sample N	National estimate*	Length of stay (days)			Average costs (year 2005 \$) <sup>†</sup>			Total annual costs (year 2005 \$) <sup>‡</sup>
			Mean	SE	Median	Mean	SE	Median	
Principal discharge diagnosis of AF (427.31)	69,678	348,131	3.59	0.04	3.00	8,412	230	5,123	2928.5
Principal discharge diagnosis of AF and catheter ablation or cardiac mapping	1,676	8,526	3.50	0.16	2.00	23,080	2613	18,228	197.4
Principal discharge diagnosis of AF and atrial cardioversion	4,744	23,851	3.43	0.11	3.00	7,873	473	4,425	188

\*The number of estimated annual hospitalizations for each query once the HCUP weighting scheme is applied. As a point of reference, there were a total of 37.2 million hospitalizations in the United States in 2001 per HCUP.

<sup>†</sup>Updated to year 2005 US dollars based on the Hospital Inpatient Services Component of the Consumer Price Index (conversion factor of 1.275 between 2001 and 2005). The dollars reported are in millions—for example, \$2856.2 million equates to \$2,856,200,000.

<sup>‡</sup>Average billed charges converted to costs (in millions) based on national average hospital cost-to-charge ratio of 0.53, estimated based on publicly available Medicare Cost Report Data.

ICD-9-CM procedure codes: 37.34 (catheter ablation of lesion or tissues of heart); 37.27 (cardiac mapping); 99.61 (atrial cardioversion).

Source. 2001 HCUP.

hospitalizations with AF as a primary diagnosis (occurring during 9% of AF hospitalizations).

AF as a primary diagnosis in the inpatient setting resulted in an estimated \$2.93 billion (year 2005 US dollars) in direct medical costs (Table 2). The mean ( $\pm$  SE) costs per AF hospital stay were \$8412  $\pm$  230, and the mean ( $\pm$  SE) LOS was 3.6  $\pm$  0.04. The mean ( $\pm$  SE) costs for AF hospital stays involving either catheter ablation or cardiac mapping were substantially higher at \$23,080  $\pm$  2613. For the top 10 discharge diagnoses in HCUP, the proportion of hospitalizations with AF as a comorbid diagnosis ranged from 31.5% in patients with CHF to 4.1% in patients with a urinary tract infection (UTI) (Table 1).

Table 3 presents estimates of the incremental economic impact of AF as a comorbid diagnosis. For all 10 diagnoses in Table 3 combined, the total annual incremental impact of AF as a comorbid diagnosis in the inpatient setting was estimated at \$1.95 billion.

This figure is conservative given that there were an additional 1.6 million hospitalizations with AF as a comorbid discharge diagnosis not among the top 10 HCUP diagnoses.

Table 4 summarizes the results of the OLS regressions used to calculate the incremental cost impact of AF reported in Table 3. The independent variables included in the 10 separate regression models are listed in the first column, and the 10 principal discharge diagnoses of interest are listed in the top row. The “+” symbol represents when the parameter estimate for a given variable was statistically significant at  $P < 0.001$ , and the parameter estimate had a positive impact on total charges. The “−” symbol represents when the parameter estimate was statistically significant at  $P < 0.001$ , and had a negative impact on total charges. For example, the variable representing the presence of AF as a secondary diagnosis (“Case”) was statistically significant in all 10 regressions, and was associated

**Table 3** Incremental impact of comorbid atrial fibrillation (AF): results of case-control analysis

Principal discharge diagnosis code	Incremental costs (\$) * due to AF per hospitalization (a)	Number of annual hospitalizations with principal discharge diagnosis code, and secondary AF diagnosis <sup>†</sup> (b)	Incremental costs (\$) * due to AF on annual basis (a) $\times$ (b)
428.0—Congestive heart failure	1,682	221,201	372,060,082
486.0—Pneumonia	1,761	111,775	196,835,775
414.01—Coronary atherosclerosis native vessel	7,286	105,980	772,170,280
410.71—Acute myocardial infarction, subendocardial	4,422	55,160	243,917,520
491.21—COPD	2,136	50,064	106,936,704
434.91—Cerebral artery occlusion, unspecified, with infarction	2,195	34,576	75,894,320
276.5—Hypovolemia	1,091	33,403	36,442,673
507.0—Food/vomit pneumonitis	2,339	30,597	71,566,383
427.81—Sinoatrial node dysfunction	1,051	30,318	31,864,218
599.0—Urinary tract infection	1,324	29,078	38,499,272
			1,946,187,227

\*Average billed charges converted to costs (in millions) based on national average hospital cost-to-charge ratio of 0.53, estimated based on publicly available Medicare Cost Report Data. Updated to year 2005 US dollars based on the Hospital Inpatient Services Component of the Consumer Price Index (conversion factor of 1.275 between 2001 and 2005).

<sup>†</sup>The number of estimated annual hospitalizations for each query once the HCUP weighting scheme is applied. As a point of reference, there were a total of 37.2 million hospitalizations in the United States in 2001 per HCUP.

Source. 2001 HCUP.

**Table 4** OLS Regressions with Total Charges as Dependent Variable

ICD-9-CM Diagnosis Code	276.5	410.71	414.01	427.81	428.0	434.91	486	491.21	507.0	599.0
Adjusted R <sup>2</sup>	0.1244	0.15	0.1627	0.0331	0.0995	0.1636	0.1638	0.1413	0.1351	0.1537
<b>Independent variable</b>										
Case	+	+	+	+	+	+	+	+	+	+
Age	+	–	–	–	–	–	–	–	–	–
Female		–	–				+	+		
White	–	–	–	–	–	–	–	–	–	–
Medium bed size hospital	+	+	+	+	+	+	+	+	+	+
Large bed size hospital	+	+	+	+	+	+	+	+	+	+
Medicare					–		–		+	–
Medicaid										
Self pay					–		–			–
Other insurance					–	–	–			
Emergency admit	+	–	–	+	+	+	+	+	+	+
Occurrence of surgical DRG	+	+	+		+	+	+	+	+	+
CABG		+	+							
<b>Comorbidity variables</b>										
CHF	+	+	+			+		+	+	+
Cardiac arrhythmias			+		+					
Pulmonary circulation disorders								+		
Peripheral vascular disorders			+		+					
Hypertension	–				–					
Paralysis		+	+		+					
Other neurological disorders	+			+	+		+			+
COPD	+	+	+	+	+	+	+		+	+
Diabetes, uncomplicated										
Diabetes, complicated					+					
Hypothyroidism										
Renal failure		+			+		+			
Liver disease					+		+			
Peptic ulcer disease	+									
AIDS										
Lymphoma										
Metastatic cancer	+				+		+			
Solid tumor without malignancy										
Rheumatoid arthritis										
Coagulopathy	+	+	+		+	+	+	+	+	+
Obesity										
Weight loss					+	+	+	+	+	+
Fluid/electrolyte disorders		+	+		+	+	+	+	+	+
Blood loss anemia	+	+			+	+	+	+	+	
Deficiency anemias	+	+	+	+	+		+	+		+
Alcohol abuse										
Drug abuse										
Psychoses	+									
Depression			–							

■ = variable excluded from regression; ■ = zero patients had comorbidity; + represents when  $P < 0.001$  and parameter estimate had positive impact on charges; – represents when  $P < 0.001$  and parameter estimate had negative impact on charges.

CABG, Coronary Artery Bypass Graft; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; DRG, diagnosis-related groups; ICD-9-CM, International Classification of Diseases (9th Edition)—Clinical Modification.

with an increase in total charges. Other interesting findings included:

- Increased age was associated with lower total charges for 7 of the 10 regression models.
- Being female was associated with lower total charges when the principal discharge diagnosis was either acute myocardial infarction (MI) or coronary atherosclerosis, but was associated with higher total charges when the principal discharge diagnosis was either pneumonia or COPD.
- White patients had significantly lower total charges (relative to nonwhite patients) in all 10 regression models.
- An emergency admission was associated with increased total charges in all but two of the regres-

sion models (i.e., acute MI and coronary atherosclerosis).

- CHF as a comorbid diagnosis was associated with increased total charges in all but two regression models (sinoatrial node dysfunction and pneumonia).
- COPD as a comorbid diagnosis was associated with increased total charges in all regression models.

### Outpatient Analyses

As with the inpatient setting, the majority of patients were 65 years or older, with a substantial proportion over the age of 75 years (Table 5). There were an estimated 5.0 million AF-related office visits, 276,000 AF-



**Table 5** Cost and distribution of atrial fibrillation-related\* visits to doctor's office, ED and OPD, 2001

Characteristic	Doctor's office (%)	ED (%)	OPD (%)
Number of visits			
Sample count	175	65	67
Count weighted <sup>†</sup> (a)	4,959,552	275,537	233,637
Average \$ per encounter (b)	235	1,111	1,241
Physician <sup>‡</sup>	135	80	135
Tests and procedures <sup>‡</sup>	55	1,025	1,062
Drugs <sup>‡</sup>	45	6	44
Total \$ (in millions) <sup>§</sup> (a) × (b)	1,165.5	306.1	289.9
Age category (years)			
≤44	1.6	5.9	0.4
45–64	11.6	19.6	30.3
65–74	30.5	19.0	22.4
≥75	56.3	55.5	46.9
Sex (% female)	47.3	54.9	49.2
Race			
White	93.1	86.8	84.0
African American	4.8	11.8	14.6
Hispanic	2.1	1.5	1.2
Other	0.0	0.0	0.2
Most common AF-related prescriptions <sup>  </sup>	Coumadin (41%) Digoxin (29%) Atenolol (10%) Amiodarone (6%)	Diltiazem (28%) Digoxin (21%) Coumadin (11%) Sotalol (3.9%)	Coumadin (46%) Digoxin (31%) Toprol XL (17%) Flecainide (2.7%)
Most common AF-related tests/procedures <sup>  </sup>	Diagnostic ultrasound heart (1.2%) DC cardioversion (1.0%) Cardiac stress test (0.9%)	Arterial blood gas measure (24%) DC cardioversion (18%) Cardiac stress test (15%)	Cardiac stress test (71%) DC cardioversion (3%)

\*Based on occurrence of ICD-9-CM diagnosis code 427.31 in any diagnosis field.

<sup>†</sup>National estimate based on applying visit weights to qualifying sample visits.

<sup>‡</sup>Physician fee assigned based on the 2004 Physicians Fee & Coding Guide (A Comprehensive Fee & Coding Reference); HealthCare Consultants of America, Inc., Augusta (GA). Tests and procedure costs were obtained from CMS's Ambulatory Payment Classification System (APC). Drug costs were obtained from Drug Topics RED BOOK 2004, updated to year 2005 US dollars based on the Consumer Price Index for prescription drugs (conversion factor of 1.05 for the period between 2004 and 2005).

<sup>§</sup>Calculated by multiplying average \$ per encounter by number of annual encounters.

<sup>||</sup>Proportion of visits with occurrence of AF-related drug or procedure

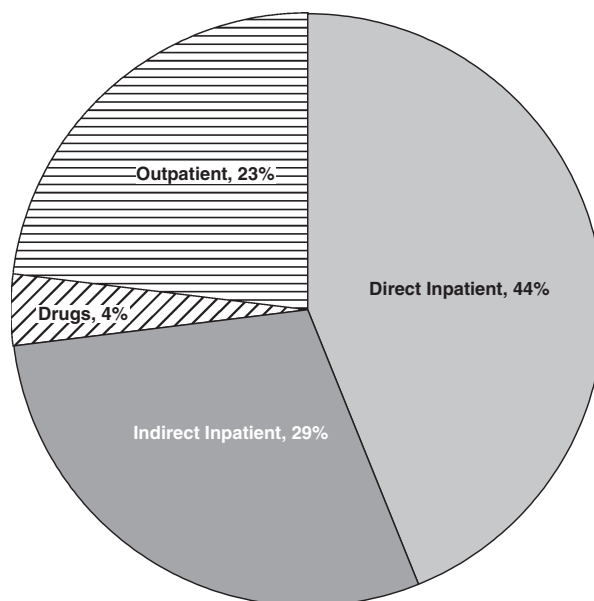
Sources: 2001 NAMCS, 2001 NHAMCS.

AF, atrial fibrillation; DC, direct current; ED, emergency department; OPD, outpatient department.

related ED visits and 234,000 AF-related OPD visits in 2001 (Table 5). Total annual direct medical costs for the ambulatory/outpatient treatment of AF were estimated at \$1.76 billion (year 2005 US dollars) with office visits accounting for 66.2% of costs, and the remainder being split among ED visits (17.4%) and hospital OPD visits (16.4%). Drug costs accounted for 19.1% of office visit costs, 0.5% of ER costs, and 3.5% of OPD costs.

### Cost of AF

Total annual medical costs for the treatment of AF in the inpatient, ER and hospital outpatient settings in the United States were estimated at \$6.65 billion (year 2005 US dollars). This estimate includes costs for all hospitalizations where AF (427.31) was the principal discharge diagnosis (\$2.93 billion), the incremental inpatient costs due to AF as a comorbid diagnosis (conservatively estimated at \$1.95 billion), and costs for all ambulatory/outpatient treatment of AF (\$1.76 billion) (Fig. 1).



**Figure 1** Distribution of inpatient and selected outpatient costs for treating atrial fibrillation.

## Discussion

This study provides an overall estimate of the direct treatment costs associated with AF across inpatient and various outpatient treatment settings and examines the incremental cost of AF as a comorbid diagnosis. Although the cost of AF is substantial, this estimate is conservative as not all encounters with AF as a comorbidity were included in this analysis. Importantly, the presence of AF increases inpatient costs of patients with both cardiovascular and noncardiovascular (e.g., pneumonia, UTI, COPD) diseases. These findings are similar to those noted by Wolf et al. [28] who used Medicare hospital claims and MedPAR data to compare costs and outcomes of patients with AF versus patients without AF; the patients with AF incurred higher costs and experienced a 20% higher mortality rate than patients without AF.

Our findings are also similar to those noted in Dell'Orfano et al.'s [29] retrospective analysis of hospital records to determine the costs of care for an acute treatment of AF in the United States. Hospital charges were highest for the group requiring direct current cardioversion (\$9892); patients who spontaneously converted had the lowest hospital charges of \$4930. In our analysis, the cost for hospitalization with a direct current cardioversion was \$7873. The cost for a catheter ablation and/or cardiac mapping was much higher at \$23,080. Clearly, more aggressive procedures result in higher costs.

To provide context for the costs of AF compared with other cardiovascular illnesses, the total direct costs for all cardiovascular disease are estimated at \$242 billion annually in the United States with CHF accounting for \$25 billion and stroke \$35 billion [30]. These estimates also include the costs of nursing home and home health care, which were not part of our analysis.

Although costs for procedures were captured in our analysis, the cost of long-term anticoagulation and stroke prevention per se was not captured in this analysis because it was beyond the scope of our analysis. The cost of stroke prevention has been previously well analyzed [7–11] with Menzin et al. [31] reporting the average costs for one full year of anticoagulation to be about \$300 and Anderson et al. [32] finding the annual anticoagulation costs to be \$600. The outpatient analysis examined drug costs; however, duration of treatment was estimated. Although drug charges are included in HCUP costs, the actual drug and treatment regimen cannot be discerned; thus inpatient drug costs could not be analyzed. As such, the estimated cost of AF of \$6.65 billion per year is underestimated as the cost for stroke prevention treatments, inpatient drug costs, remaining encounters with AF as a comorbid condition, and inpatient physician fees are not

included. Additionally, indirect costs of AF (e.g., work loss, reduced leisure time, quality-of-life impact), which are likely to be significant, could not be assessed in this analysis.

The racial disparity noted in our study is similar to that noted by Baine et al. [33] in an analysis of Medicare beneficiaries with a higher prevalence of white men and women being hospitalized with AF than other races. Using National Hospital Discharge Survey records, Khairallah et al. [34] found 71.5% of the population to be white, 5.6% to be African American and 20.8% to be “not specified.” Approximately 88% of the primary AF diagnoses group was white compared with a proportion of 69% white for all US hospitalizations in 2001 [35]. The cause of this racial variation would be interesting to explore because it is not known whether this is related to the epidemiology of the disease or barriers to health care.

Studies in the United States and other countries have found that the number of hospitalizations for AF has increased substantially in recent years [36–39]. This could be due to a true increase in AF prevalence, changes in how AF is recorded or coded as a diagnosis, or both.

There are a number of limitations associated with this cross-sectional analysis. First, the HCUP billed charges data do not include fees for hospital-based physician services. To be conservative, the analysis did not attempt to estimate these costs. Second, neither the HCUP nor NAMCS/NHAMCS databases included the actual costs of care for reported services. An average charge-to-cost ratio was applied uniformly across all discharges, and this could either overestimate or underestimate the actual costs of care at a given institution. Third, the study utilized cross-sectional data that did not allow for a longitudinal tracking of patients and their full episodes of care for AF-related illness. In addition, the lack of longitudinal data limited the ability of the study to identify all patient comorbidities, because only the comorbidities listed on the selected visits could be captured for the analyses. Lastly, the cost of AF as a comorbid condition was only captured for 10 HCUP diagnoses leaving the incremental cost associated with 1.6 million other hospitalizations not known. As such, the estimates presented here are conservative.

As the prevalence of AF increases with age, AF is anticipated to become an increasing burden on the health-care system. Future research should consider possible areas of reducing costs such as those demonstrated by Zimetbaum et al. [40], where practice guidelines on treating AF were instituted in the ED. These guidelines reduced the hospital admission rate from 74% to 38% without affecting clinical outcomes. Such interventions could have a tremendous financial impact in reducing the cost of AF.

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